Mapping Dark Atomic and Molecular Gas in the Galaxy

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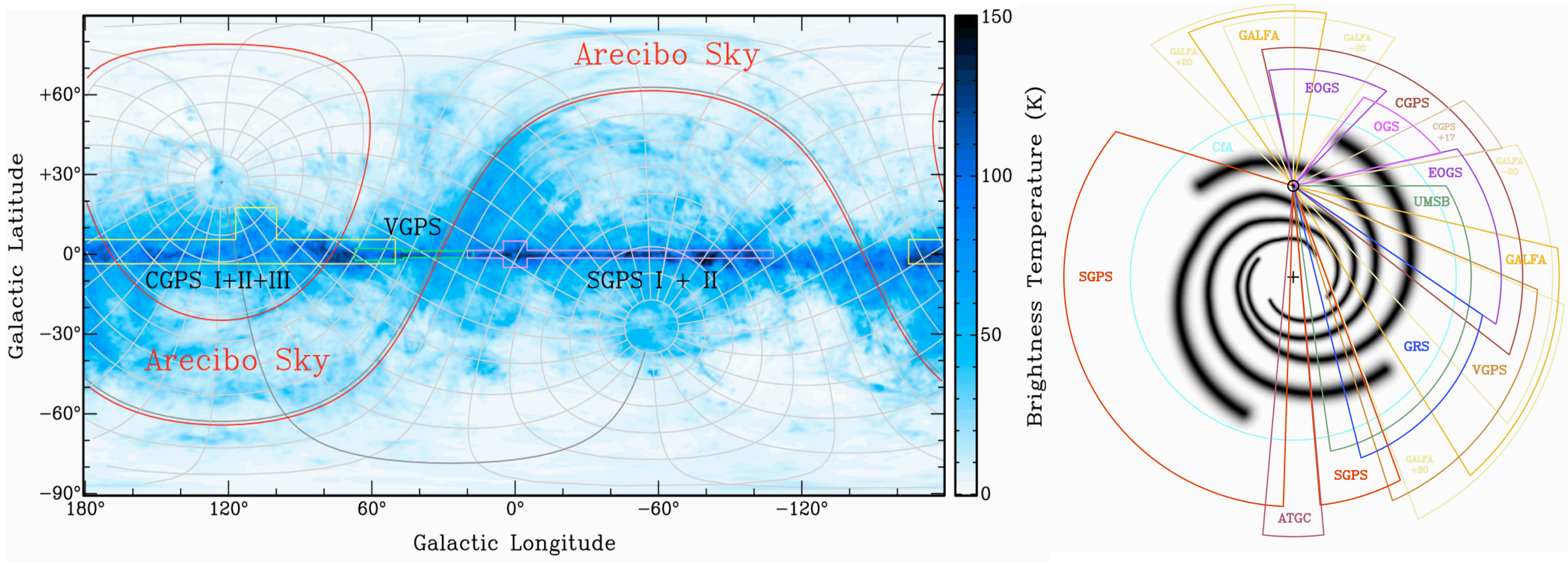


Figure 1. High-resolution 21cm H I and 2.6mm CO survey coverage on the sky (above; LAB H I image, Kalberla et al. 2005) and in the Galactic disk (above right; spiral arm model from Taylor & Cordes 1993). Arecibo is well suited to faint, high latitude emission studies, while the CGPS, VGPS, and SGPS are excellent for small-scale, low-latitude absorption. The grid is J2000 coordinates.

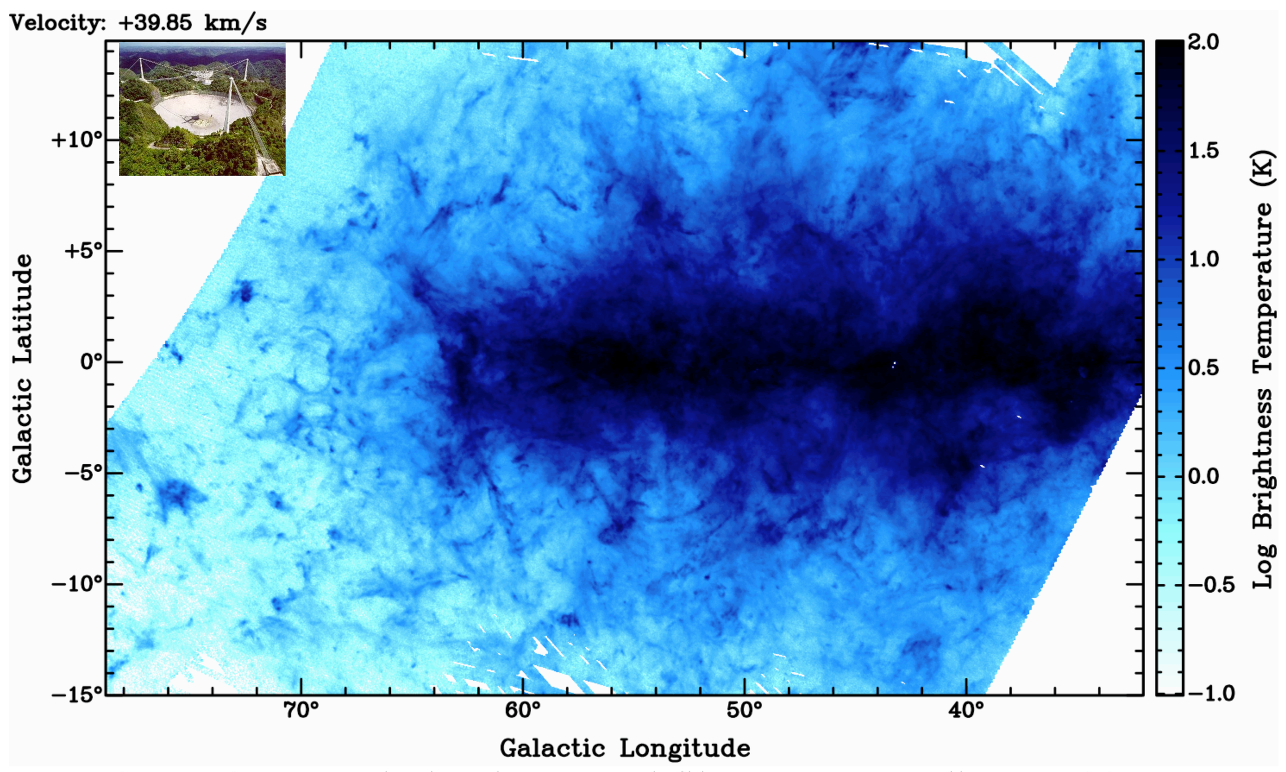


Figure 2. H I emission knots and filaments extending > 500 pc off the plane (I-GALFA 4' beam survey; Gibson et al. 2012). Many of these features are cold and may contain ``dark'' gas -- either opaque H I or CO-free H_2. Far-IR dust photometry is crucial for this investigation, just as H I and CO spectral line image cubes can greatly aid ISM dust studies.

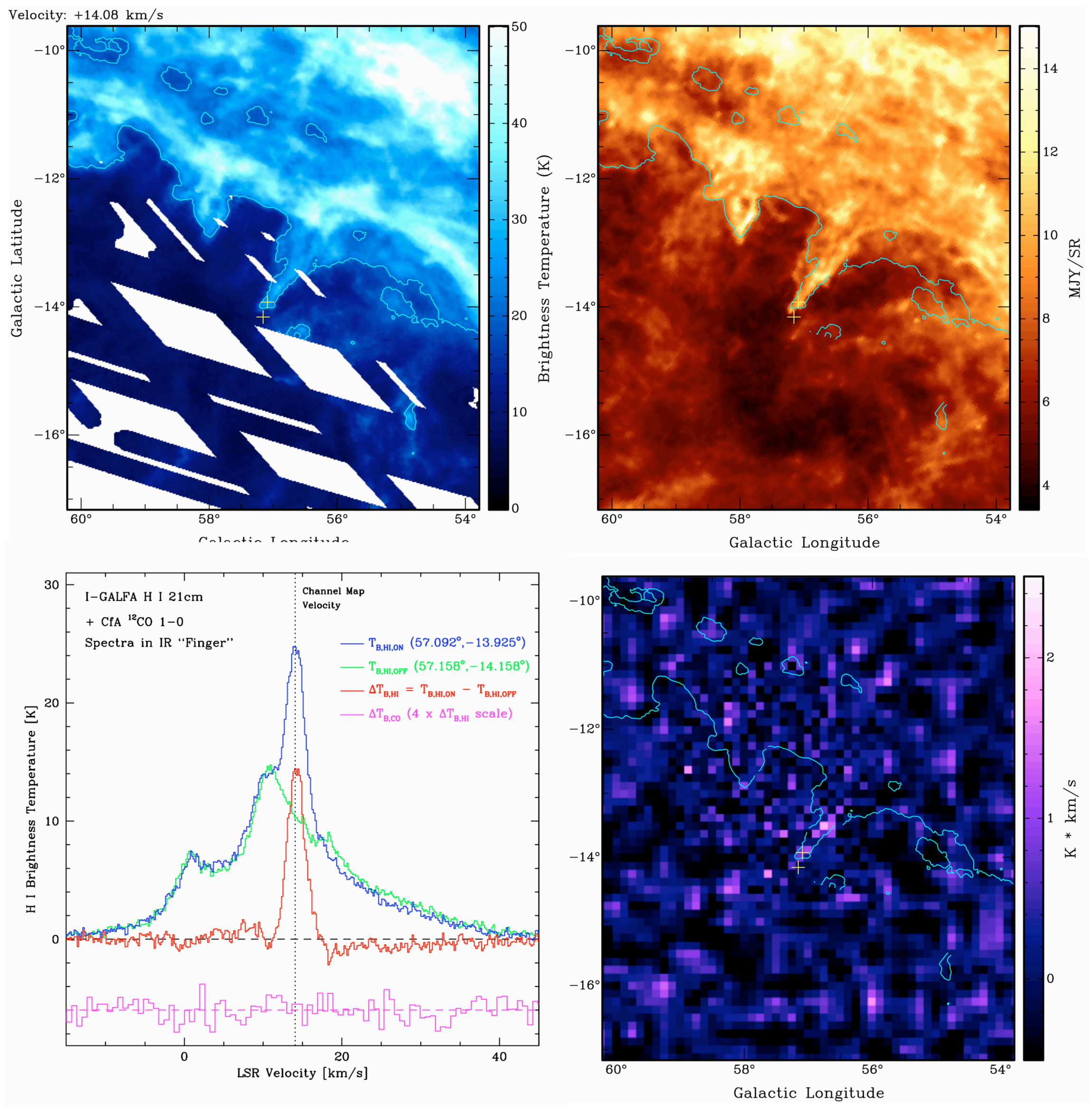


Figure 3. Prominent dark-gas filament in Arecibo narrow-line H I emission (NHIE; left panels) and IRIS 100μm dust (upper right; Miville-Deschenes & Lagache 2006), with little or no CfA ^{12}CO 1-0 emission (lower right; Dame, private comm.); the contour is T_B(H I) = 20 K. $N_{HI}(\tau << 1) \sim 8\times10^{19}$ cm^{-2}, while multiplying the ON-OFF 100μm intensity by 1×10^{20} cm^{-2} / MJy/sr (Reach et al. 1994) yields N_H(dust) ~ 5×10^{20} cm^{-2}, near the ^{12}CO self-shielding limit but above that for dark H_2 (Snow & McCall 2006).

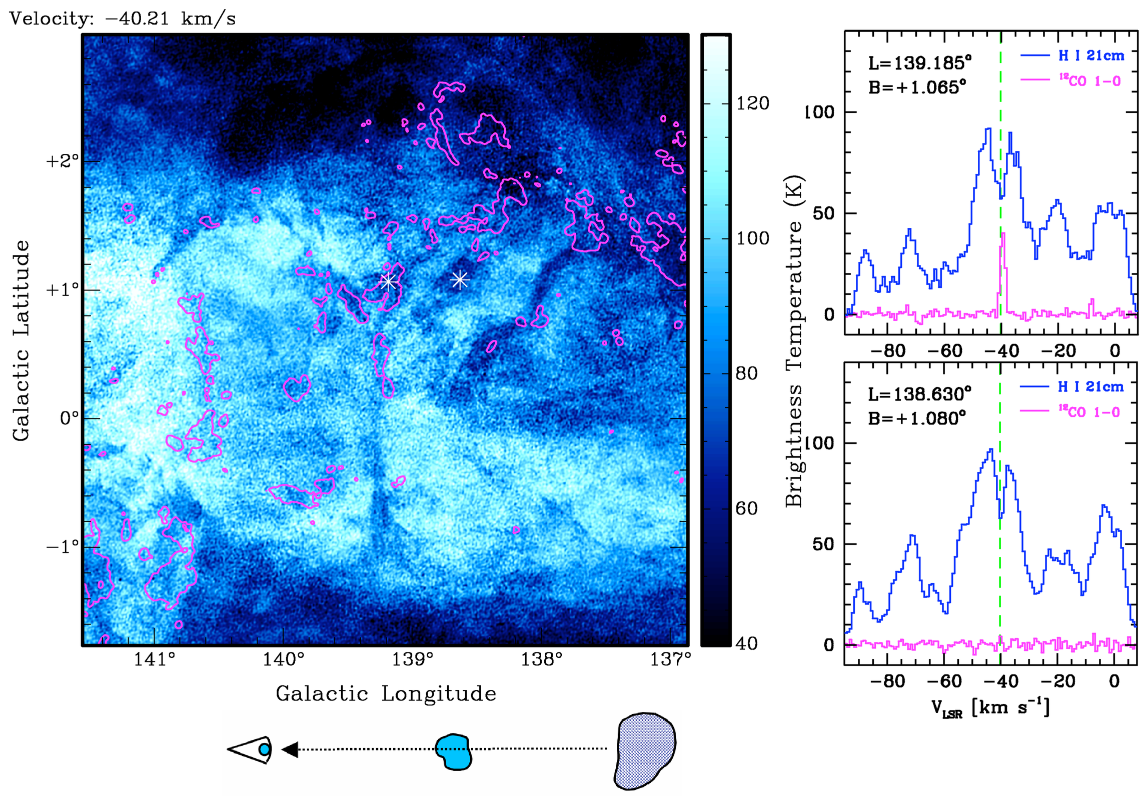
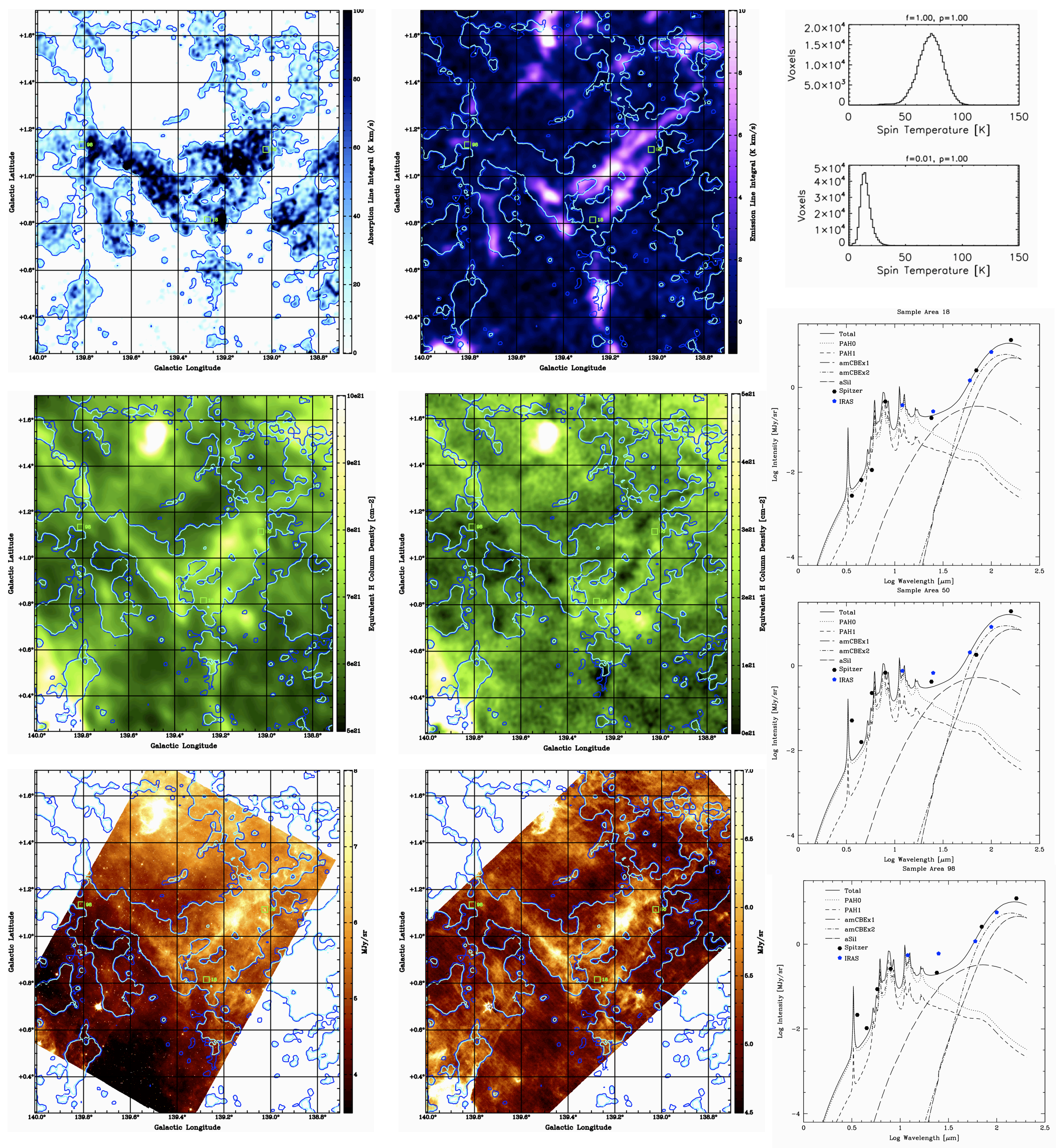


Figure 4. H I self-absorption (HISA) against warmer background H I emission (sketch) arises from atomic gas that is too cold to explain easily if it is not outside molecular clouds (Wolfire et al. 2003), and yet HISA shadows often appear separate from CO emission, particularly in the outer Galaxy. The panels above show 1' beam CGPS H I (blue; Taylor et al. 2003) and OGS ^{12}CO 1-0 (magenta; Heyer et al. 1998). The clouds shown are ~ 2 kpc away in the Perseus arm, where they may be forming H_2 and CO downstream of the spiral shock before forming new stars (Gibson et al. 2005).

Figure 5. We have extracted HISA ON-OFF brightness difference maps (top left panel below; HISA contour in all maps) and have analyzed their properties using simple physical relationships (Gibson et al. 2000). We find temperatures like those of typical cold atomic or molecular gas, depending on the HISA partial pressure (top right). We also obtained N_{H2}(CO) from the line integral (top center) using an empirical factor $X_{CO} = 1.0\times10^{20}$ cm^{-2} / (K km/s) and N_H(dust) from I_{100} (center left) as in Figure 3. When column densities of HISA, H I emission, and CO are all subtracted from the scaled dust column (center), residuals are near zero in the CO cloud cores, but significant IR excess appears in many areas, e.g., near *l,b* = 139.9°, +1.4°. We are pursuing more sophisticated SED fits of Spitzer data (bottom 8 + 24μm panels, right plots) with DustEM (Compiegne et al. 2011).



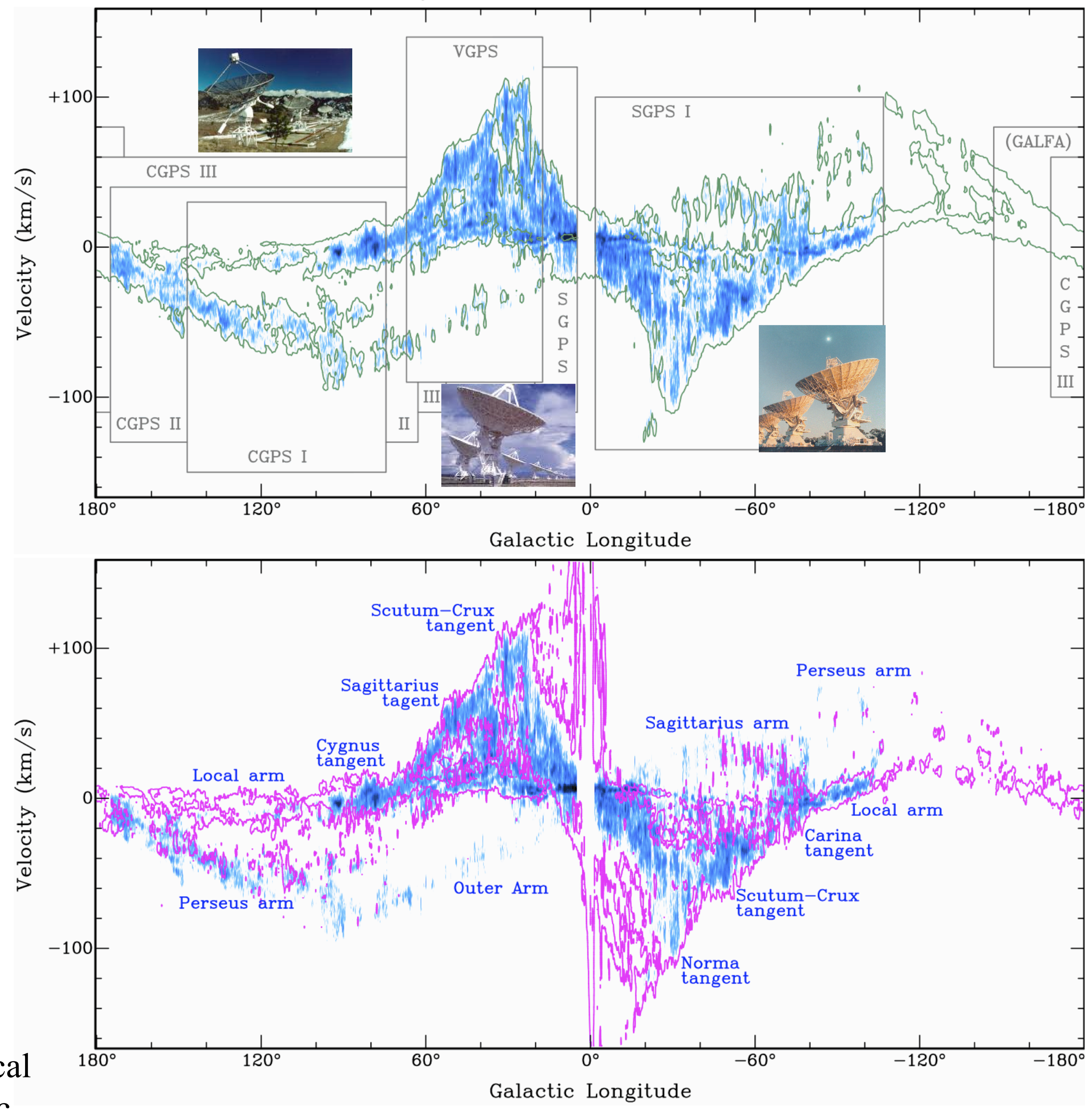
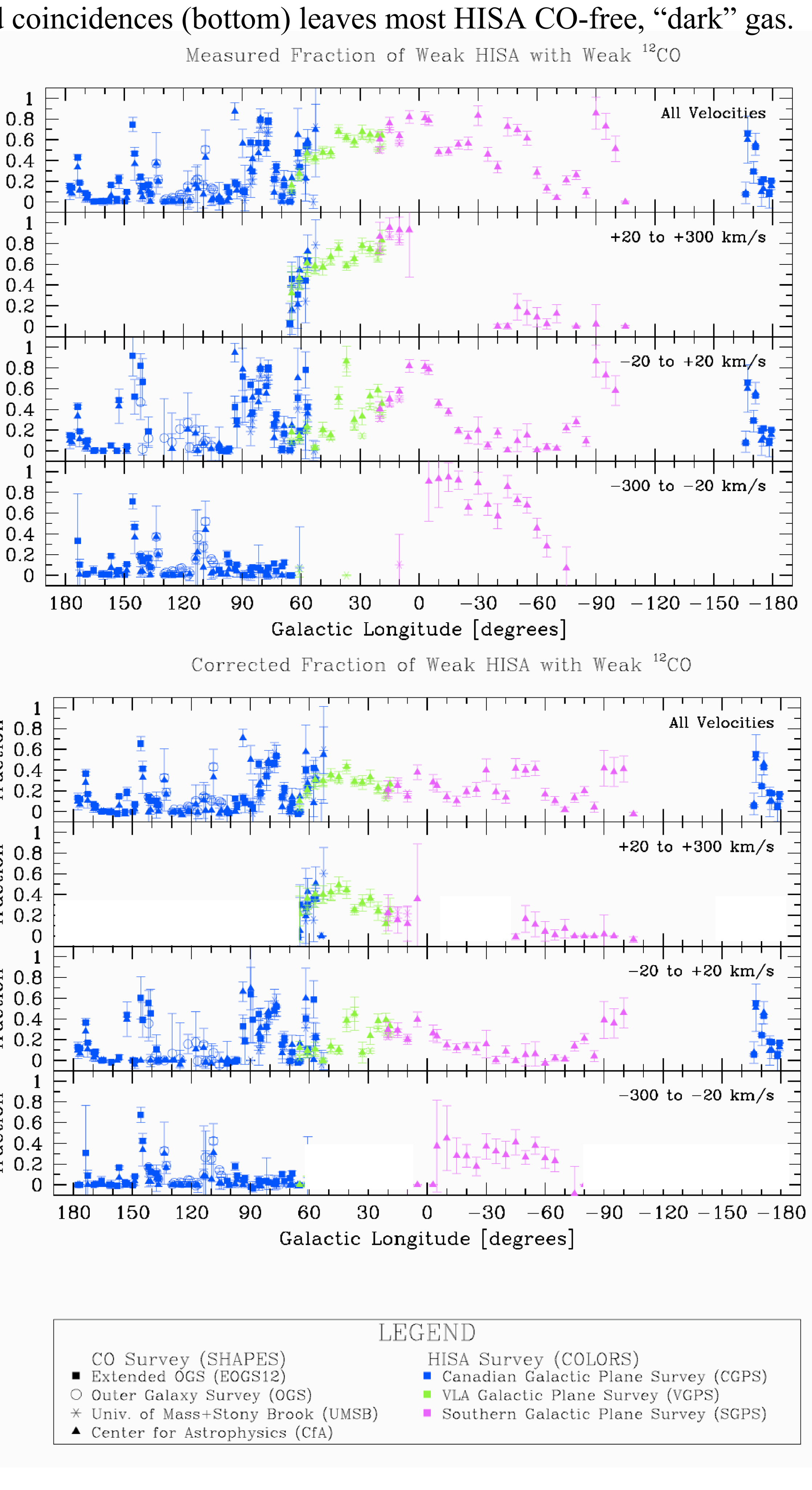


Figure 6. We have mapped HISA in the CGPS, VGPS, and SGPS, where it is widespread (top; Gibson 2010; green contour is search region). HISA traces spiral arms in the outer Galaxy and tangent points in the inner Galaxy, where arm structure is hard to distinguish (above). CfA CO (magenta; Dame et al. 2001) matches HISA poorly in the outer Galaxy and better in the inner Galaxy, as borne out by the fraction of HISA pixels containing CO vs. longitude (below). However, this is partly due to random alignments, which are more likely in the inner Galaxy where both CO and HISA are more abundant; subtracting such expected coincidences (bottom) leaves most HISA CO-free, "dark" gas.



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